A REVIEW OF CLOSED BOTTOM STREAM CROSSING STRUCTURES (CULVERTS) ON FISH - BEARING STREAMS IN THE KAMLOOPS FOREST DISTRICT, JUNE 2001.

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Abstract

A review of closed bottom culverts was conducted to assess whether the fish and fish habitat provisions of the *Fisheries Act* were being achieved. A total of thirty-one culverts, installed on fish-bearing streams, in the Kamloops Forest District were assessed. At each culvert site the likelihood of juvenile fish passage and the maintenance of fish habitat was assessed. Only one of the thirty-one culverts assessed met Fisheries and Oceans objectives for juvenile fish passage and maintenance of fish habitat. Two other culverts were likely to provide juvenile fish passage but failed to maintain fish habitat. Fisheries and Oceans fish passage and fish habitat protection objectives associated with closed bottom stream crossing structures are rarely being achieved in the Kamloops Forest District. It is recommended that clear span, open bottom structures, i.e. bridges, be used on all fish bearing streams.

Résumé

Une étude des buses à fond fermé a été effectuée pour évaluer dans quelle mesure les dispositions de la *Loi sur les pêches* étaient respectées. Au total, trente et une buses installées sur des cours d'eau abritant du poisson ont été évaluées dans la circonscription forestière de Kamloops. Pour chaque buse, la probabilité d'accès des poissons juvéniles et le degré de préservation de l'habitat du poisson ont été évalués. Une seule des trente et une buses étudiées s'est révélée conforme aux objectifs de Pêches et Océans Canada pour ce qui est de l'accessibilité aux jeunes poissons et de la préservation de l'habitat du poisson. Deux autres buses offraient de bonnes chances de passage aux jeunes poissons mais n'étaient pas satisfaisantes pour ce qui est de la préservation de l'habitat. Les objectifs de Pêches et Océans Canada en matière de passage du poisson et de la préservation de l'habitat sur les cours d'eau enjambés par des structures à fond fermé sont rarement atteints dans la circonscription forestière de Kamloops. On recommande la construction systématique de structures ouvertes, c'est à dire de ponts, lorsqu'il est nécessaire d'enjamber des cours d'eau contenant des poissons.

1.0 Introduction, Limitations and Background

1.1 Introduction

Fisheries and Oceans, Canada (DFO) in the BC Interior – South participated in a Kamloops Forest District review of closed-bottom stream-crossing structures (culverts) during the week of June 11, 2001. The review was commissioned and designed by the forest district's Forest Ecosystem Specialist (FES) of the Ministry of Environment, Lands and Parks (MELP). Fisheries and Oceans participated in this review to determine whether the fish and fish habitat provisions of the *Fisheries Act* are being achieved when closed bottom structures are installed on fish-bearing streams.

The following sections of the *Fisheries Act* are relevant to the installation of culvert stream crossings:

Fisheries Act.	Section 20, 26	Ensure safe fish passage.
Fisheries Act.	Section 35	Protect fish habitat.
Fisheries Act.	Section 36	Prevent sedimentation of fish-bearing waters.

Traditionally, a stream crossing design was considered successful when it maximised the speed and efficiency of water and debris passage with the smallest possible culvert (Dent and Allen, 2000). Since the implementation of the *Forest Practices Code of British Columbia Act* (FPC) in 1995 and the Stream Crossing Guidebook in 1997, DFO has assumed that culverts were being designed and installed to provide for upstream migration of juvenile fish and the protection of fish habitat.

Unfortunately, this has not been the case. In 2000, DFO published the results of a culvert audit in a technical report titled No Net Loss of Fish Habitat: An Audit of Forest Road Crossings of Fish-Bearing Streams in British Columbia, 1996 –1999 (Harper and Quigley, 2000). The results of this audit demonstrated that culverts, i.e., corrugated metal pipes, installed on fish-bearing streams result in the harmful alteration, disruption and destruction (HADD) of fish habitat.

The purpose of this culvert review was to assess the effectiveness of current culvert installations in maintaining juvenile fish passage and fish habitat in the Kamloops Forest District.

1.2 Limitations

The field review was designed to provide a snapshot of the current state of culverts in the Kamloops Forest District. The parameters measured could not account for the seasonal fluctuations in water flow and velocity within the culvert, the timing or life stage of migrating fish or the total loss of fish habitat associated with culvert installation. The data collected at the culvert sites permitted evaluation of the provision of juvenile fish passage and the determination of the loss/disruption of instream fish habitat only at the time of assessment.

1.3 Background

1.3.1 Fish Passage

In addition to the British Columbia's *FPC* requirement to provide fish passage at stream crossing sites (*Timber Harvesting Practices Regulation* s21 (3) and *Forest Road Regulation*: Part 3 s13 (1)(h)) the federal *Fisheries Act* s20 (1) also requires fish passage. Section 20 (1) of the *Fisheries Act* reads,

> *...Every obstruction across or in any stream where the Minister determines it to be necessary for the public interest that a fish-pass should exist shall be provided by the owner or occupier with a durable and efficient fish-way or canal around the obstruction, which shall be maintained in a good and effective condition by the owner or occupier, in such place and such form and capacity as will in the opinion of the Minister satisfactorily permit the free passage of fish through it.*

Despite the legal requirement to provide fish passage designing culverts that allow for the passage of juvenile fish is a relatively new approach to stream-crossing installations. Fish swimming abilities vary by age and species, as do their timings of upstream migrations and movements. The 1997 FPC Stream Crossing Guidebook recommended that during the design and selection of a stream crossing structure, consideration be given to the weakest species requiring passage and the smallest size of fish moving or migrating within that group - usually, juvenile fish (Poulin and Argent, 1997). Further, the definition of fish, as defined by the *Fisheries Act*, includes the juvenile life stages of fish. Therefore, the requirement of section 20(1) to ensure fish passage should be considered a requirement to provide juvenile fish passage.

Sustainable fish populations are as dependent upon the opportunity for upstream migration of juvenile fish as they are upon the opportunity for upstream migration of adult fish. Juvenile fish migrate upstream for a number of reasons: to avoid predation, to seek appropriate habitat for given life stages (e.g. cooler temperatures, lower velocities), or to seek less populated areas with better opportunity for food and cover (Bustard and Narver, 1975; Cedarholm and Scarlett, 1981; Everest, 1973; Fausch and Young, 1995; Gowan et al 1994; Hartman and Brown, 1987; Reiser and Bjornn, 1979; Shirvell, 1994). There is evidence that juvenile fish that are able to reach more favourable habitat conditions are larger in size and have better survival rates (Bustard and Narver, 1975; Skeescik, 1970).

Unlike adult fish, juvenile fish have greater limitations in terms of their ability to jump and then swim upstream against fast flowing water for extended periods of time (Bell, 1986). Fish seem to conserve energy when navigating through culverts rather than utilising their full athletic potential (Belhke, 1989). Therefore, juvenile fish require very low gradients (<0.5%), low water velocity and unimpeded access to the culvert (Dent and Allen, 2000).

Young fish also require refuge from fast flowing water and the opportunity to rest before moving upstream through a culvert. Velocity refuges can be created within a culvert by retaining substrate within the culvert barrel to simulate a natural streambed (Dent and Allen, 2000). This strategy is referred to as embedment. Ultimately, juvenile fish passage objectives can be successfully achieved with installations that maintain the natural streambed (i.e. open bottom arches and bridges).

The development of road systems and stream crossings without regard to fish passage can jeopardise the biological integrity of a watershed by truncating the available habitat (Dent and Allen, 2000).

1.3.2 Fish Habitat

The *Fisheries Act* describes fish habitat as *'...spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly to carry out their life processes.'* Section 35(1) of the *Fisheries Act* reads *'No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat' (HADD).* Any change in fish habitat that reduces its capacity to support one or more life processes of fish is considered a HADD.

Fisheries and Oceans has determined that culverts cause HADD to fish habitat in most cases because they and their construction alter, disrupt and/or destroy streambanks, the stream bed and contribute to the removal of riparian vegetation. Loss of habitat, however, does not end at the inlet or outlet of the culvert because the culvert also influences the hydraulic characteristics of adjacent areas (Dane, 1978). Therefore, the spawning, rearing and food production capabilities of the stream can be affected in areas not directly affected by the culvert (Dane, 1978).

Culverts alter the natural flow regime for fish life cycle needs. They remove light, stream bank complexity, nutrient input, sources of large woody debris and the ability of the stream channel to adjust and rehabilitate itself in response to hydraulic factors. It is important to note that <u>all</u> stream crossing structures have the potential to harmfully alter, disrupt or destroy fish habitat due to removal of riparian vegetation. Also, the potential introduction of sediment to streams via surface run-off from roads and stream bank erosion may harmfully alter fish habitat.

2.0 Methods

2.1 Monitoring Objectives

Fisheries and Oceans participated in the Kamloops Forest District culvert review with the intent of answering the following questions:

1. What percentage of culverts, in the Kamloops Forest District, are likely to provide juvenile fish passage?
2. Are the fish and fish habitat protection provisions of the *Fisheries Act* being achieved when closed bottom structures are installed on fish-bearing streams?

2.2 Site Selection

All closed bottom stream crossing structures, in the Kamloops Forest District, referred to the Ministry of Forests (MOF) and/or the MELP and installed after the implementation of the *FPC* (June 15,1995) were selected and field reviewed during the week of June 11, 2001 through to June 18, 2001. A total of thirty-three culvert sites were identified. Two of these sites, however, were not evaluated: a culvert on a non-fish-bearing stream and a culvert that was not reviewed by DFO staff. The remaining thirty-one culverts were assessed by DFO.

2.3 Field Methodology

At each crossing the following assessment parameters were evaluated by DFO:

- Pipefill materials
- Structure type
- Structure diameter
- Structure length
- Embedment
- Pipe gradient
- Outlet velocity
- Natural stream channel width (bankfull width).

An example of a completed data form is presented in Appendix 1.

2.4 Site Descriptions

Each of the thirty-one culvert assessment sites was located within the Kamloops Forest District on streams classified as S3 or S4 as per the Forest Practices Code fish-stream classification system. The natural stream channel width of the streams ranged from 0.8m to 4.5m. Five culverts were on streams classified as S4 streams (natural stream channel width less than 1.5m). Twenty-six culverts were on S3 streams (natural stream channel width ranging from 1.5 to 5.0m) – of these, seventeen culverts were on streams less than 2.5m in width and nine were on streams that had natural stream channel widths in excess of 2.5m.

Fish presence (rainbow trout, in particular) at each site was documented as determined, suspected or unlikely. Fish presence was determined at sixteen sites, suspected at nine and thought unlikely at six sites.

Twenty-two of the sites were culverts installed as replacements for damaged or condemned stream crossing structures and nine culverts were initial stream crossings. Two types of closed bottom culverts were reviewed – round corrugated metal pipes and pipe arch corrugated metal pipes. These structures ranged from 1000mm to 3600mm in diameter and 10.6m to 24.3m in length. The culvert gradients ranged from 0.5% to 12%. Three culverts were installed at gradients of 0.5%, thirteen culverts were installed at gradients in the range of <0.5% to > 3%, eight were installed in the range between 3 and 6% and seven were installed at gradients that exceeded 6%.

2.5 Fish Passage

<u>Objective 1.</u> What percentage of culverts, in the Kamloops Forest District, have a likelihood to provide juvenile fish passage?

Rather than making direct observations of fish passage or taking detailed water velocity measurements, it was assumed that if a culvert met the following criteria or set of criterion it would meet the juvenile fish passage objective:

1. Culvert installed at ≤ 0.5% gradient with no outlet drop (Dent and Allen, 2000).

Or

2. Attainment of the following:
   - 1997 Stream Crossing Guidebook installation objectives[1]:
     - Embedded pipe arch culverts should be buried a minimum of 0.3m or 20 percent of their height below the stream bed – whichever is greater – with a gradient of ≤ 5 percent (Poulin and Argent, 1997).
     - Embedded round culverts should be buried a minimum of 0.3m or 20 percent of their diameter – whichever is greater – with a gradient ≤ 3.5 percent (Poulin and Argent, 1997).

- Simulated streambed or contiguous rockfill in culvert barrel (Dent and Allen, 2000).
- Maintained natural stream channel width (Dent and Allen, 2000).

Velocity measurements were taken at the outlet end of the culvert and compared to the burst swimming speeds of juvenile rainbow trout. Measuring velocity at the outlet end of the culvert assessed the opportunity for juvenile fish to enter a given culvert (access). The velocity was measured in the middle of the outlet, in the barrel of the culvert, at 0.6 of the water depth using a Swoffer® Current Velocity Metre, Model 2100. This measurement was not representative of the flow across the cross section of the culvert or along the culvert length.

The velocity measurement was compared to the burst-swimming speed of juvenile rainbow trout as documented by Hunter and Mayor (1986) in their Analysis of fish swimming performance data. Burst swimming speed was used because fish may be required to use burst-swimming speeds to negotiate the inlet or outlet of the culvert (Powers and Orsborn, 1985). The smallest size class of juvenile rainbow trout (50mm) and its corresponding burst swimming speed (0.3 – 0.4 m/sec) was used as a benchmark. If the maximum water velocity at the outlet of the culvert was $\leq$0.4 m/sec, the culvert was considered accessible to juvenile rainbow trout.

2.6 Fish Habitat

Objective 2. Are the fish and fish habitat protection provisions of the *Fisheries Act* being achieved when closed bottom structures are installed on fish-bearing streams?

Fish habitat can be divided into two categories: stream habitat and riparian habitat. Riparian habitat was not assessed. The following categories of stream habitat loss associated with culvert stream crossings were assessed:

- **Habitat loss due to encroachment (m^2):** the amount of instream habitat lost due to encroachment of the culvert on the stream channel width. The habitat loss associated with encroachment includes the natural streambanks and substrate lost due to channel infilling (Fig.1, A) (Harper and Quigley, 2000). Habitat lost due to encroachment was measured by subtracting the culvert diameter from the bankfull width and multiplying by the culvert length.

- **Benthic habitat loss and disruption (m^2):** the amount of benthic habitat lost or disrupted due to culvert installation (Fig. 1, B) (Harper and Quigley, 2000). Benthic habitat represents the substrate that supports the community of algae and invertebrates that provide food for fish, spawning areas for adult fish and rearing areas for juvenile fish. Benthic habitat disruption/loss was measured by multiplying the length of the culvert by the diameter of the culvert, and does not include benthic habitat lost due to encroachment.

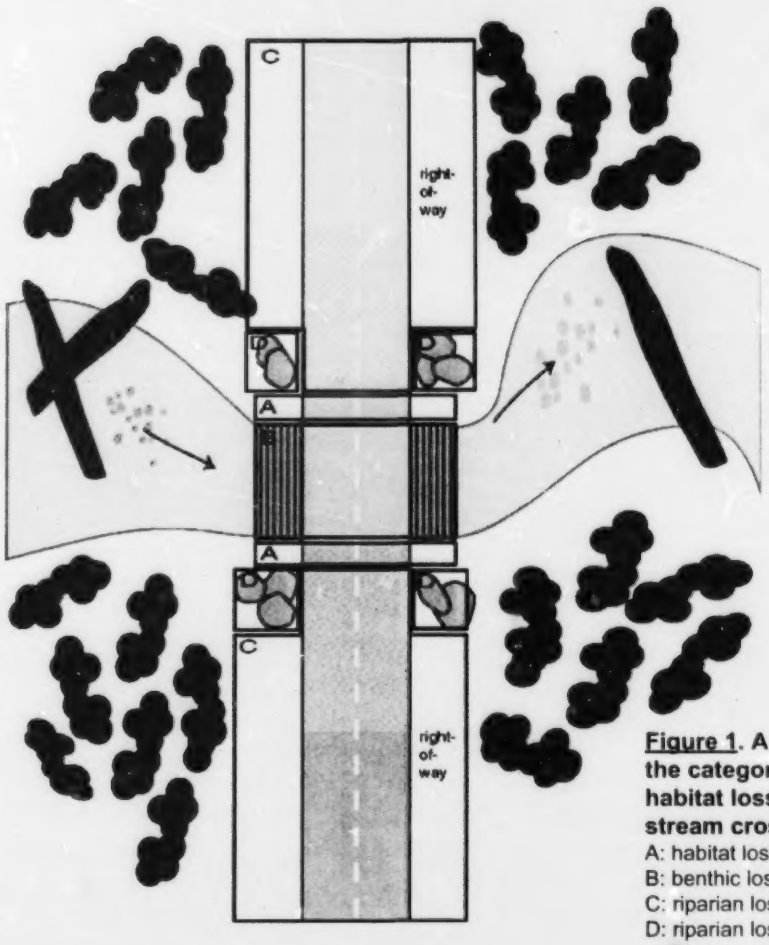

Figure 1. A representation of the categories of potential fish habitat loss associated with stream crossings.
A: habitat loss due to encroachment;
B: benthic loss;
C: riparian loss due to road;
D: riparian loss due to crossing (Harper and Quigley, 2000).

2.6.1 Sedimentation

Quantitative measurements of sediment either suspended in water or deposited on fish habitat were not taken during the review. Instead, visual observations of potential sediment sources were recorded. At each crossing, road drainage, road right-of-way clearing and site re-vegetation was assessed as adequate or inadequate. Livestock damage associated with stream bank trampling was also noted.

Road drainage was considered adequate if the ditch sumps were functioning or if there was no evidence of sediment introduction to the stream channel. Failure of either one these criteria resulted in an inadequate designation.

Road right-of-ways were considered adequate if the removal of riparian vegetation within the right of way width appeared to be minimised. If the removal of riparian vegetation within the road right-of-way width was considered excessive then the right-of-way was considered inadequate. Site re-vegetation was considered adequate if vegetation had taken hold (i.e. grass seeding and brush, willows, or alder were evident). If exposed soil or bare rock was present and there was no evidence of grass seeding or replanting the re-vegetation was considered inadequate.

Livestock damage was assessed through evidence of stream bank trampling and excessive browse.

If the culvert site met the fish passage criteria, did not encroach on the stream channel or have the potential to introduce sediment to the stream the fish and fish habitat provisions of the *Fisheries Act* were considered met. If any one of these criteria was not met the fish and fish habitat provisions of the *Fisheries Act* were considered not met.

3.0 Results

In the following section the results are presented separately for replacement culverts and new installations. The culverts were evaluated by comparing the data collected in the field to the criteria presented in Section 2.5 and 2.6. The evaluation criteria were derived from Dent and Allen (2000), the installation objectives for embedded culverts identified in the Stream Crossing Guidebook (Poulin and Argent, 1997) and the habitat parameters identified by Harper and Quigley (2000).

3.1 Fish Passage

Objective 1. What percentage of culverts, in the Kamloops Forest District, have a likelihood to provide juvenile fish passage?

A summary of the data evaluated to assess the likelihood of juvenile fish passage is presented in Appendix 2.

Twenty-two of the culverts reviewed were replacement structures for previously failed or condemned stream crossing structures. Based on the criteria described in Section 2.5, three (14%) of the twenty-two replacement culverts were likely to pass juvenile fish (Fig. 2). Based on the same criteria none of the nine newly installed culverts were likely to pass juvenile fish (Fig. 2).

When juvenile rainbow trout access was assessed using the velocity measurements taken in the field three (16 %) of the nineteen replacement culverts (for which velocity was recorded) appeared likely to provide juvenile rainbow trout access to the culvert (Fig. 3). For new installations, one (15%) of the seven culverts (for which velocity was recorded) was likely to provide fish access to the culvert (Fig. 3).

Figure 4 illustrates a culvert that provided juvenile fish passage. Figure 5 illustrates a culvert that failed to provide juvenile fish passage.

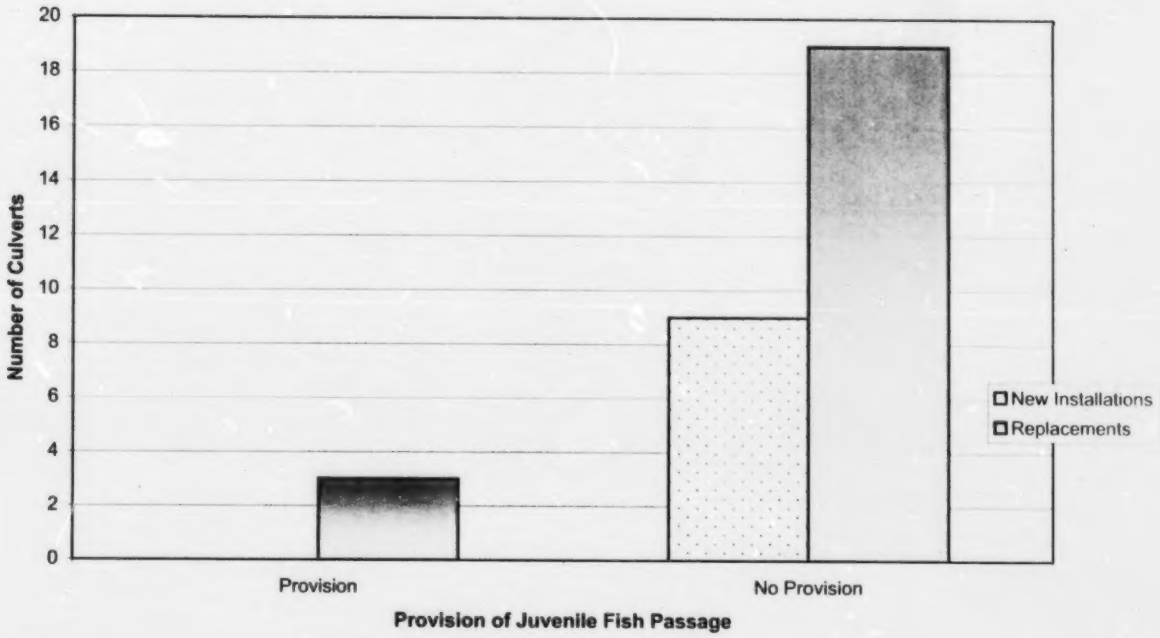

Figure 2. Provision of juvenile fish passage through culverts in the Kamloops Forest District.

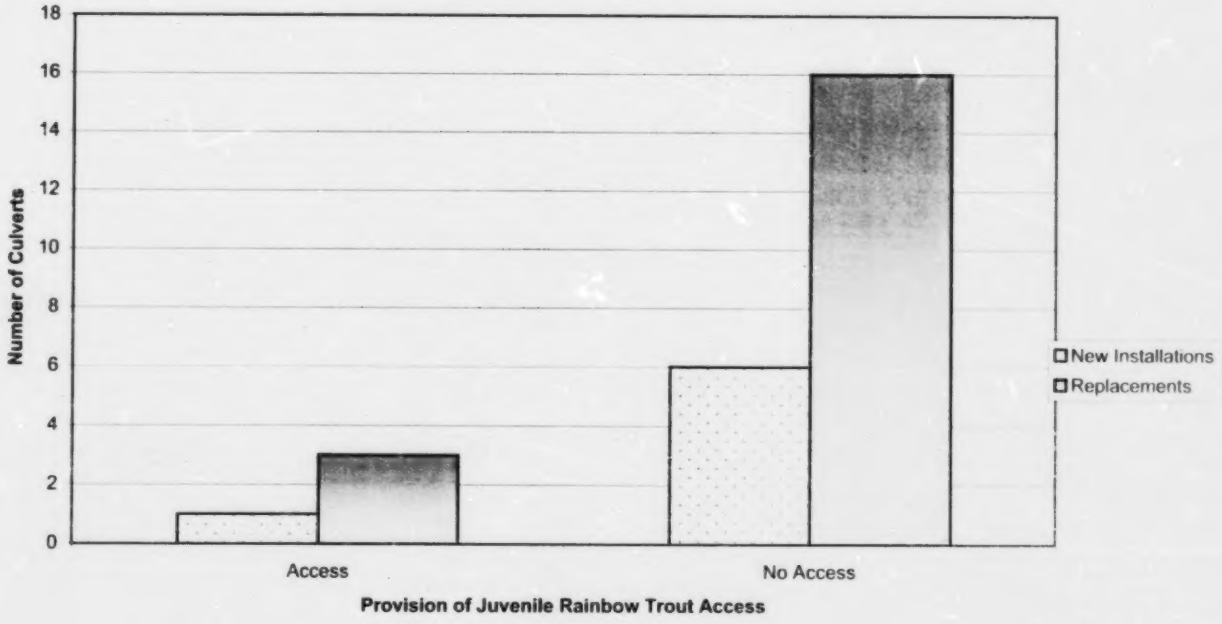

Figure 3. Provision of juvenile rainbow trout access to culverts in the Kamloops Forest District.

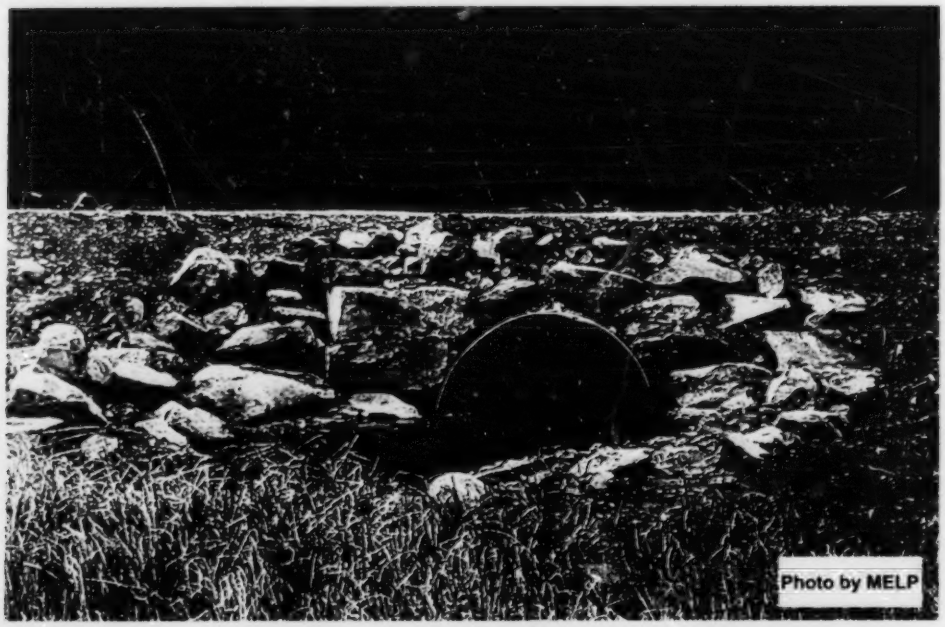

Figure 4. A culvert, in the Kamloops Forest District, that provided juvenile fish passage.

Figure 5. A culvert, in the Kamloops Forest District, that failed to provide juvenile fish passage.

3.2 Fish Habitat

Objective 2. Are the fish and fish habitat protection provisions of the *Fisheries Act* being achieved when closed bottom structures are installed on fish-bearing streams?

A summary of the habitat loss associated with encroachment of culverts on the natural width of the stream channel and the alteration, disruption or destruction of benthic habitat associated with the installation of culverts is presented in Appendix 3.

Six (27%) of the replacement culverts did not encroach upon the bankfull width of the channel (Fig. 6). The remaining sixteen (74%) replacement structures encroached upon the natural width of the channel (Fig. 6) and resulted in a total loss of 193.5 m^2 of fish habitat. Each of the twenty-two replacement culverts resulted in a loss of habitat due to the alteration, disruption and/or destruction of natural stream banks and stream bottom (736.7 m^2 in total). Instream fish habitat altered by the installation of replacement culverts was 930.2 m^2.

Six (67%) of the new culvert installations did not encroach on the natural width of the stream channel (Fig. 6); however, three (33%) installations did and resulted in a total loss of 11.9 m^2 of fish habitat (Fig. 6). Again, each of the new installations resulted in streambank and streambed alteration, disruption and/or destruction (215.5 m^2 in total). Instream fish habitat altered by the installation of new culverts was 227.7 m^2.

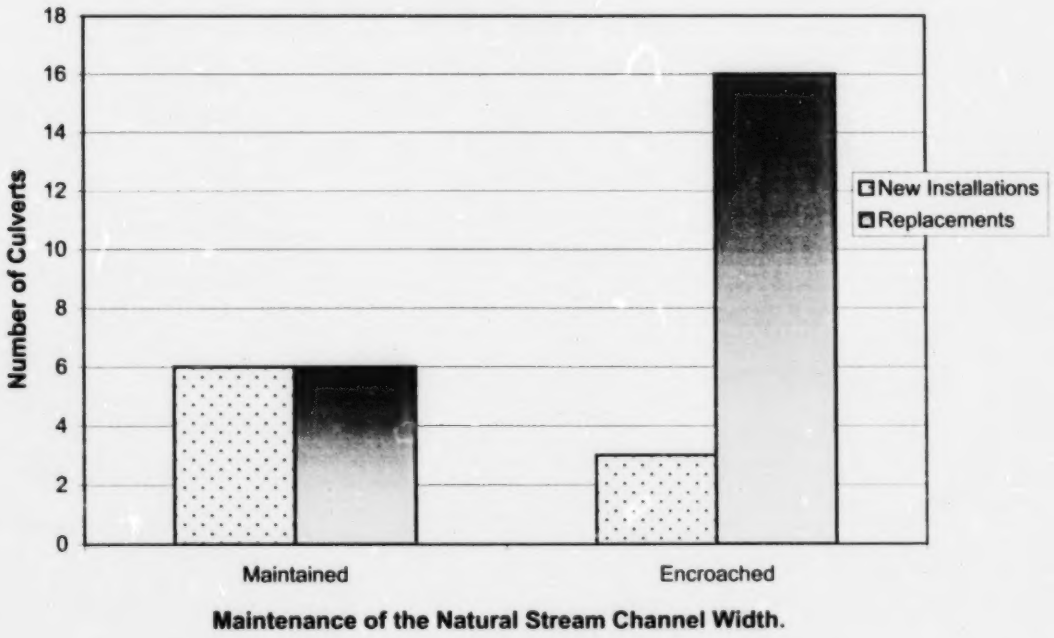

Figure 6. Summary of culvert success, in the Kamloops Forest District, at maintaining natural stream channel width.

Figure 7 is an example of a culvert that maintained the natural stream channel width. Figure 8 is an example of a culvert that failed to maintain the natural stream channel width.

Figure 7. A culvert, in the Kamloops Forest District, that maintained the natural stream channel width.

Figure 8. A culvert, in the Kamloops Forest District, that failed to maintain the natural stream channel width.

3.2.1 Sedimentation

A summary of the assessment of potential sediment delivery agents is presented in Appendix 3b.

Thirteen (59%) of twenty-two replacement culverts and five (56%) of the nine newly installed culverts assessed had adequate road drainage measures in place (Fig. 9). Six (27%) of the replacement culvert sites and five (56%) of the newly installed culverts were adequately re-vegetated (Fig. 9). Thirteen (59%) of the replacement culverts had adequately sized road right-of-ways (Fig. 9). All of the newly installed culverts had adequate road right-of-ways (Fig. 9).

Livestock trampling of streambanks did not occur at eleven (50%) of the replacement culvert sites (Fig. 9). The newly installed stream crossing sites did not exhibit signs of streambank trampling by livestock (Fig. 9).

The following two figures illustrate sediment delivery agents observed during the field review. Figure 10 demonstrates the effects of livestock trampling on the streambanks and Figure 11 shows an example of insufficient re-vegetation at a crossing site.

Figure 9. Number of culvert sites in the Kamloops Forest District with limited potential to deliver sediment at the crossing sites.

Figure 10. **A culvert site, in the Kamloops Forest District, where livestock trampling is a delivery agent for sediment.**

Figure 11. **A culvert site, in the Kamloops Forest District, which has not been sufficiently re-vegetated.**

3.3 Summary of Findings

The findings of the Kamloops Forest District culvert review further substantiate the concerns raised in the DFO's No Net Loss of Fish Habitat: An Audit of Forest Road Crossings of Fish-Bearing Streams in British Columbia, 1996 – 1999 (Harper and Quigley, 2000). One (3%) of the thirty-one culverts reviewed in the Kamloops Forest District had both likelihood to pass juvenile fish and met the habitat provisions of the *Fisheries Act* (Fig.12). Figures 13 and 14 are photographs of the inlet and outlet conditions associated with the one crossing that met Fisheries and Oceans fish and fish habitat provisions. Table 1 provides a summary of the fish passage and fish habitat evaluations and the success rates for each.

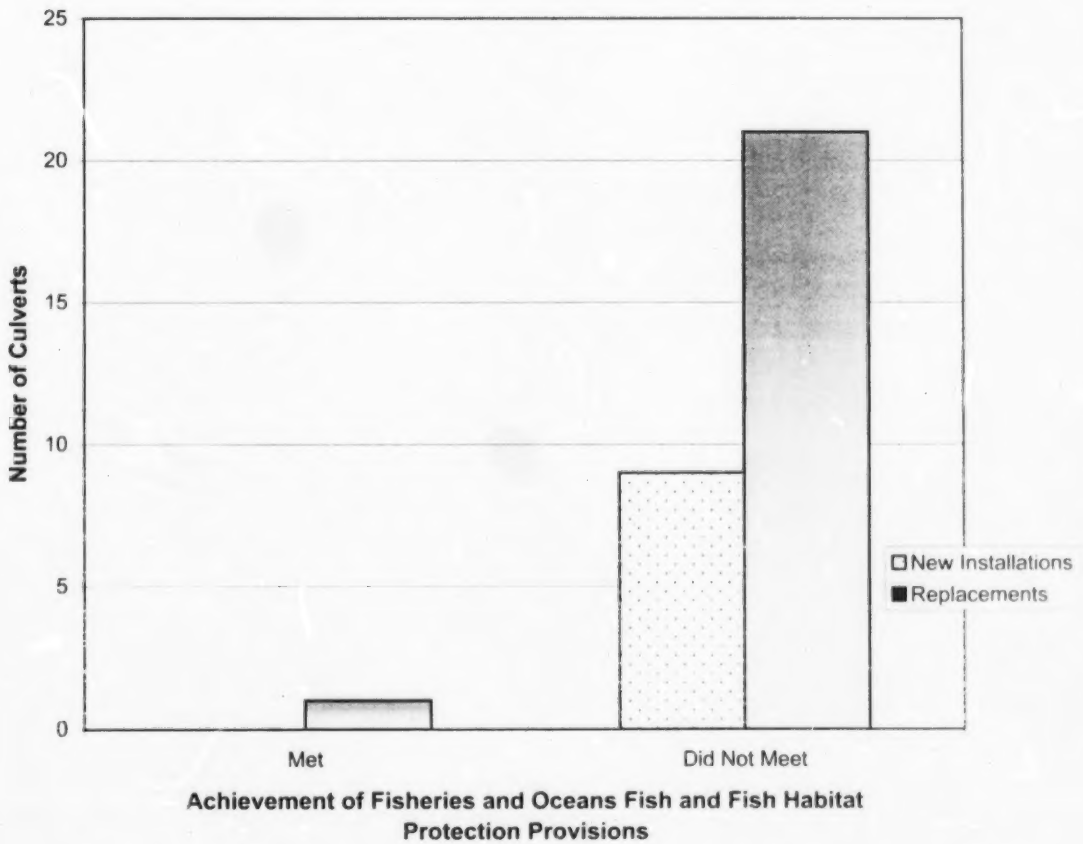

Figure 12. Number of culverts, in the Kamloops Forest District, that met Fisheries and Oceans fish and fish habitat protection provisions.

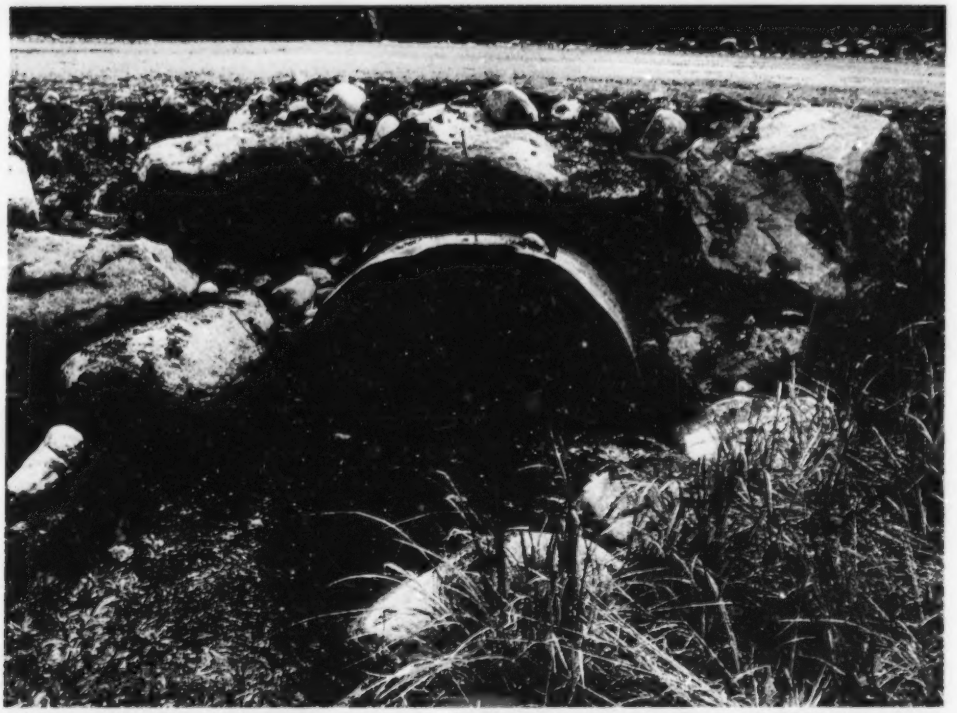

Figure 13. The inlet of a culvert, in the Kamloops Forest District, that met Fisheries and Oceans fish and fish habitat provisions.

Figure 14. The outlet of a culvert, in the Kamloops Forest District, that met Fisheries and Oceans fish and fish habitat provisions.

Table 1. Summary of Kamloops Forest District Culvert Review Findings

Culvert Type	Evaluation Results					
	Fish Passage	Fish Access	Stream Crossing Guidebook Objectives	Maintained Stream Channel Width	No Potential for Sediment Delivery	DFO Fish and Fish Habitat Provisions
	A	B				
Replacement	3/22	3/22	4/22	6/22	3/22	1/22
New Installation	0/9	1/9	0/9	6/9	4/9	0/9
Totals	3/31	4/31	4/31	12/31	7/31	1/31
Success Rate %	**10**	**13**	**13**	**39**	**23**	**3**

A= based on physical parameters; B= based on velocity measurements

4.0 Discussion

4.1 Fish Passage

Objective 1. What percentage of culverts, in the Kamloops Forest District, have a likelihood to provide juvenile fish passage?

Each of the thirty-one culverts reviewed in the Kamloops Forest District were installed in streams classified as S3 or S4 through the *FPC* stream classification system as identified in the *Fish-Stream Identification Guidebook (December, 1995 or August, 1998)* and the *Riparian Management Area Guidebook (December 1995)*. Given that fish presence (specifically, rainbow trout) was documented as confirmed, suspected or unlikely at the stream crossing sites DFO's expectation was that juvenile fish passage (specifically for rainbow trout) be provided at each culvert site. The DFO's expectation for the provision of juvenile fish passage was based on the *Fisheries Act* definition of fish and on the application of the *precautionary principle*.

The *precautionary principle* as defined at the United Nations Convention on Biological Diversity (1992) reads:

> *Where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat* (Chutter, 2000).

When the precautionary principle was applied to closed bottom stream crossing structures, the *threat of significant reduction or loss of biological diversity* was determined to be truncated fish habitat for all life stages of fish. The *lack of full scientific certainty* was considered to be the lack of determination of fish presence and the requirement for the provision of juvenile fish passage at all stream crossing sites was considered the *measure(s) to avoid or minimize* [the] *threat* of truncated fish habitat. Hence the DFO's expectation of the provision of juvenile fish passage at each of the thirty-one culvert sites.

In contrast, the MELP designated environmental official[2] (the FES) required that fish passage be provided at nineteen of the thirty-one culvert sites. Of these sites, fifteen were located on streams where fish presence had been determined and four were located on streams where fish presence was suspected. On streams where fish presence was deemed unlikely (six sites) fish passage was not required. It should be noted that fish passage for juvenile fish appeared to be achieved at only three (16%) of the nineteen sites.

The provision of juvenile fish passage was assessed using the criteria described in Section 2.5. These criteria were used because they provided the best indication of the physical conditions (low gradient, unimpeded access and refuge areas) necessary to ensure juvenile fish passage through a culvert. Three of the thirty-one culvert sites reviewed provided these conditions.

Velocity measurements (Section 2.5) were compared to the burst swimming speed of 50mm juvenile rainbow trout to provide an indication of whether juvenile rainbow trout had access to the culvert (velocity readings $\leq$ 0.4m/sec were considered accessible). Based on this comparison, four of the thirty-one culvert sites appeared to be accessible to juvenile rainbow trout.

Of the three culverts that met the physical criteria for juvenile fish passage one did not meet the velocity criteria of $\leq$ 0.4m/sec. Of the four culverts that met the velocity criteria two did not met the physical criteria. Given the limitations associated with the velocity measurements (seasonal fluctuation in water flow and velocity within the culvert[3]), if a culvert did not meet the physical criteria it was considered impassable to juvenile fish. Therefore, the two culvert sites that met the velocity criteria were not considered to provide fish passage because the physical criteria had not been met. However, based on the limitations of velocity measurements associated with culverts, the culvert that met the physical criteria and not the velocity criteria was deemed to provide juvenile fish passage because the conditions necessary for passage through the culvert were present.

That being said, the three culverts that met the physical criteria were the only culverts of the thirty-one evaluated considered to provide juvenile fish passage.

[2] *A person employed in the* [MELP] *who is designated by name or title to be a designated environmental official by the minister of that ministry for the purpose of a provision of* [the FPC] *or the regulations that is set out in the designation (FPCBC Act, 1998)*

[3] *(Robison, 2001).*

At ten (45%) of the twenty-two replacement crossing sites juvenile fish passage appeared to be impeded due to the replacement of log bridges (Fig.15a) with culverts (Fig. 15b). Prior to culvert installation fish would have had unimpeded passage to habitat upstream of the crossing site. Juvenile fish passage was prevented entirely at six of these replacement crossings.

It is also important to remember that twenty-eight of the thirty-one culverts assessed impeded or prohibited the upstream migration of fish at some point during their life cycle. The available habitat upstream of these impassable culverts was not measured. Subsequently, fish within the streams associated with the impassable culverts could be denied access to hundreds of metres or kilometres of important habitat.

4.2 Fish Habitat

Objective 2. Are the fish and fish habitat protection provisions of the *Fisheries Act* being achieved when closed bottom structures are installed on fish bearing streams?

DFO has a responsibility to protect fish habitat. Any change in fish habitat that reduces a stream's capacity to support one or more life processes of fish is considered a HADD. In assessing the potential for an activity to cause a HADD, DFO habitat managers identify changes to the biophysical attributes that would be of a type and magnitude sufficient to render the habitat less suitable, or unsuitable for supporting fish life processes.

Habitat management decisions pertaining to section 35 of the *Fisheries Act* are made in conjunction with DFO's Policy for the Management of Fish Habitat. DFO's long-term policy objective for the management of fish habitat is the achievement of an overall net gain of the productive capacity of fish habitats. Progress toward this objective is achieved through the conservation of the current productive capacity of fish habitats (No Net Loss), the restoration of damaged fish habitats and the development of new fish habitat.

For the purposes of this review, culverts were classified in two categories: as replacements (structures replacing a pre-existing stream crossing) or new installations (first time stream crossings). The Policy for the Management of Fish Habitat applies to each classification.
Theoretically, a replacement culvert should result in a net gain of habitat, since the replacement structure should re-establish fish passage and/or improve the hydraulic circumstances associated with the stream crossing. Unfortunately, based on the stream crossings assessed, with the exception of one culvert, this was not the case. The culvert that was successful in achieving the No Net Loss objective was successful due to the fact that it was a replacement structure that restored access to previously unavailable fish habitat. This culvert improved juvenile rainbow trout passage, achieved the SCG installation objectives for culvert embedment and slope and did not encroach on the bankfull width of the channel.

Figure 15a. **A stream crossing, in the Kamloops Forest District, that provided fish passage prior to culvert installation.**

Figure 15b. **The culvert that replaced the log bridge in Figure 15a. Note, it did not provide juvenile fish passage.**

At ten (45%) of the twenty-two replacement crossing sites fish habitat was further degraded by the installation of culverts resulting in a net loss of fish habitat. These replacement sites were originally log bridges that were replaced with culverts. Given that these replacement structures were replaced under the Forest Practices Code one would assume the *FPC* Stream Crossing Guidebook installation objectives for embedment and slope would have been implemented. The implementation of these objectives was not observed at any of the eleven culverts that replaced log bridges. Further, eight of the ten culverts that replaced log bridges encroached upon the bankfull width of the stream channel and resulted in a reduction of the fish habitat associated with the site. With the exception of one replacement culvert, the replacement culverts that replaced damaged or inaccessible culverts failed to improve fish habitat and resulted in a net loss of fish habitat.

The installation of new culverts also had an impact on fish habitat due to alteration of and disturbance to the streambed and streambanks. None of the nine new installations achieved the Stream Crossing Guidebook installation objectives of embedment and slope. Five (55%) of the nine were sufficiently sized, i.e., they did not encroach on the bankfull width of the channel. Consequently, the productive capacity of the fish habitat, at each of the nine new culvert installations, was not conserved and therefore, the No Net Loss principle was not achieved.

Fisheries and Oceans Canada must also ensure that no person deposits or permits the deposit of a deleterious substance (sediment) to fish-bearing waters (*FA s36 (3)*). Three techniques for prevention of sedimentation and erosion were evaluated in this review – road drainage, re-vegetation, and size of road right-of-way.

Nine (41%) of the replacement culvert sites had the potential to deliver sediment to the stream via inadequate road drainage as did four (44%) of the new installation sites.

Grass seeding was the most prevalent form of bank re-vegetation observed throughout the stream crossing review in the Kamloops Forest District. Livestock damage to stream banks was typically associated with crossings that were grass seeded. The planting of deciduous whips or stakes was an uncommon re-vegetation practice and occurred at just three (10%) of the thirty-one sites.

Road right-of-ways appeared to be minimised at the new culvert installation sites; however, this was not the case for most of the right-of-ways at replacement culvert sites. In some cases, the culvert replacement site had been moved away from the original crossing site, subsequently increasing the habitat loss associated with the crossing. Other than occasional grass seeding little was done to mitigate or restore the riparian area associated with the old crossing site.

5.0 Conclusions and Recommendations

As identified in Section 3.3 this review further substantiates the concerns raised previously in the No Net Loss of Fish Habitat: An Audit of Forest Road Crossings of Fish-Bearing Streams in British Columbia, 1996-1999. The authors of the No Net Loss Audit concluded that,

> *...Knowledge of the impacts of stream crossings on fish habitat are well established, as are the best management practices to mitigate these impacts. Despite this knowledge, there is a continued lack of compliance with fish habitat protection legislation and policy with regards to stream crossings... No Net Loss of habitat cannot be achieved with the current stream crossing practises* (Harper & Quigley, 2000).

Conclusions from the Kamloops Forest District closed bottom structure stream crossing review are the same. Ten percent of the closed bottom structure stream crossings reviewed in the Kamloops Forest District provided juvenile fish passage. Three percent of the closed bottom stream crossing structures met the fish and fish habitat provisions of the *Fisheries Act*.

The following section summarises the conclusions of this review and makes recommendations for achieving fish passage, fish habitat and sedimentation objectives as they pertain to the fish and fish habitat provisions of the *Fisheries Act*.

5.1 Fish Passage

Objective 1. What percentage of culverts, in the Kamloops Forest District, have a likelihood to provide juvenile fish passage?

5.1.1 Conclusions

- Ten percent of the closed bottom structure stream crossings reviewed in the Kamloops Forest District provided juvenile fish passage.
- Fish passage objectives are not being achieved at the majority of replacement or first time installation culvert stream crossings.
- There is discrepancy, with regards to the provision of fish passage in the Kamloops Forest District, between the DFO's expectations for fish passage and the expectations of the Kamloops Forest District FES.
- The presence/absence of fish must be established prior to the installation of culverts.
- From a fish passage perspective, closed bottom structures are rarely effective for stream crossings on fish-bearing streams.

5.1.2 Recommendations

- As per section 20 of the *Fisheries Act* fish passage should be restored at sites where culverts have impeded or prohibited fish passage.

- If fish presence/absence has not been determined stream crossing structures must be designed and installed to provided juvenile fish passage.
- The federal and provincial resource agencies (i.e. MOF, Ministry of Water, Land and Air Protection[4] (MWLAP) and DFO) need to work together to harmonise the criteria for determining fish passage.
- Given that fish-passage objectives are rarely achieved on fish-bearing streams with closed bottom structures, clear span, open bottom structures, i.e. bridges, should be used on S3 and S4 streams.

5.2 Fish Habitat

Objective 2. Are the fish and fish habitat protection provisions of the *Fisheries Act* being achieved when closed bottom stream crossing structures are installed on fish-bearing streams?

5.2.1 Conclusions

- The fish habitat protection and conservation objectives of the DFO, are rarely being achieved when closed bottom structures are installed on fish-bearing streams. Three percent of the closed bottom stream crossing structures in the Kamloops Forest District met the fish and fish habitat provisions of the *Fisheries Act*.
- Closed bottom structures installed in fish bearing streams have negative impacts on fish habitat.
- Replacement culverts on fish bearing streams have not resulted in a net gain of fish habitat and in some cases have caused a net loss.
- Efficacy and compliance monitoring of culverts on fish bearing streams appears to be inconsistent and irregular.
- Sediment is being managed but improvement is needed in areas of road drainage and prevention of stream bank erosion.
- Livestock grazing and watering plays a role in accelerated bank erosion at many stream crossing sites, especially if grass seeding is the sole source of re-vegetation.
- Riparian re-vegetation is often inadequate at replacement stream crossing sites.

5.2.2 Recommendations

- Clear span, open bottom structures that do not alter or disrupt the stream banks and streambed should be used on S3 and S4 streams.
- The installation of culverts on fish bearing streams must be referred to DFO.
- The installation of replacement culverts in fish-bearing streams must be referred to DFO if the culvert installation will result in a disturbance to the streambed or streambanks and/or an excessive loss of riparian vegetation.
- Replacement culverts should maintain or better existing conditions at the crossing site (i.e. improve habitat conditions and/or restore fish passage).

[4] Provincial agency formerly known as MELP.

- Replacement structures should be installed in the original footprint of the stream crossing.
- Proponents and agencies (DFO, MWLAP and the MOF) should conduct routine efficacy (i.e. maintenance) and compliance monitoring.
- Ensure that best management practices as they pertain to road drainage, sumps and prevention of stream bank erosion are implemented.
- Explore opportunities to limit livestock access to stream crossing sites; e.g. exclusion fencing.
- Willow whips and stakes should be used in conjunction with grass seeding as a re-vegetation method on a more consistent basis.

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Appendix 1.

Example of a Field Data Sheet

Fish Culvert Inventory Form - Kamloops District

2001/07/12 pjh Version2

Gaz_locat: Watching Creek tributary W-site2 | CP_Ref: W-619.2 | Road#: 2120 | km: | ReviewDate: 2001/06/14

DataGathe: Phil Holman | Vic_Lake: | Regulatory Stratum: code replacement

GPSReadout: 50 55.283; 120 29.132

DEOStructureReqd: No fish passage required, CW

DEOCondition1: Sediment control CW and fish | DEO_TCDate1: 998/07/27

DEOCondition2: Ditch sediment management | DEO_TCDate2:

DEOCondition3: minimize bank vegetation disturb.

☑ NO_DEOFishPassReqd

☑ PrevStructure | PrevDate: 1980/01/01

PrevStructureType: log culvert

PrevLength: 0.0 m | PrevDiam: 0 mm

PrevIssue1: collapsed (picture)

PrevIssue2:

S_CodeOriginal: S3 | S_CodeNow: S3 | ☐ S_CodeDownclass

☑ StreamDataCollected | Fish presence: expected | Fish SPP1: RB | ☑ Fish_U/S | ☑ LakeFish_U/S

BankfulWidth: 2.2 m | Fish SPP2: | ☑ Fish_D/S

BottomAtCrossing: gravel and cobble | ThalwegDepth: 0 cm | HabitatUse: none, u/s riffle 11%

Pool Location: | GradientPool: 0.0 % | VelocityPool: 0 m/s

Riffle location: downstream | GradientRiffle: 5.0 | VelocityRiffle 1.09 | ☑ BankStabilOK

BankStabilIssue: ok

☑ StructureInstalled | InstalledYear: 1999 | ☐ Pipefilled | PipefillMaterials: none, not required

ActualInstalledType: PACMP | A_StructureDia: 2200 mm | A_StructureLong: 140.0 m | Embedment: ok

MaxCulvWaterDepth: 50 cm | A_PipeGradient: 6.5 % | ☑ CulvGradientOK | ☑ CulvertEngineerFunctionOK

Inlet velocity: 0 m/s | Outlet velocity: 0 m/s | InletCondition: ok

FishPassable: not required | ☑ InstalledEnvOK | InPipeCondition: ok, non-filled

ScourDepositionIssues: some scour, prior crossing | OutletCondition: ok

FishHabU/S: none

☐ RWImpactsOKSumm

Observer Facing Downstream

☐ RWRevegOK | RWRevegAge: 22 Months

RWClearing: excessive (pre & post photos)

RWComment: need deciduous planting

RWDrainU/SLeft: no issue

RWDrainU/SRight: no issue

RWDrainD/SLeft: no issue

RWDrainD/SRight: no issue

Summary

☑ NoFishPassReqd | ☑ PrevStructure | ☐ RWImpactsOKSumm

FishPassable: not required | FishPresence: expected | RB | S_CodeNow: S3

Actual InstalledType: PACMP | ☑ Installed EnvOK | Regulatory Stratum: code replacement

OverviewRecommend1: Plant deciduous u/s and d/s

OverviewRecommend2:

OverviewComment1: If rethought, pipefill to reduce scour | OverviewComment2:

Appendix 2.

Data used to Evaluate the Likelihood of Juvenile Fish Passage

Appendix 2a. Evaluation of the opportunity for juvenile fish passage through culverts in the Kamloops Forest District during the week of June 11 through 18, 2001.

	Replacement Structure Location	FPC Class	Fish Presence	Passage Inferred by FPC Class	Passage Required by FES	Passage Required by DFO	Culvert Gradient	SCG Objectives[1]	Simulated Stream bed[2]	Stream Channel Width Maintained	Likelihood of Juvenile Fish Passage
1	Darlington	S3	RB	Yes	Yes	Yes	0.5	Yes	SS	Yes	Yes
2	Whitewood 77-7	S3	(RB)	Yes	Yes	Yes	0.5	Yes	SS	No	Yes
3	Taweel	S3	RB	Yes	Yes	Yes	2.5	No	NM	Yes	No
4	Bogmar Lake	S3	RB	Yes	Yes	Yes	0.9	No	NM	Yes	No
5	Wyse Lake	S3	(RB)	Yes	Yes	Yes	1.5	No	NM	No	No
6	Akehurst Lake	S3	(RB)	Yes	Yes	Yes	3.0	Yes	SR	No	No
7	Caverhill A54114	S3	(RB)	Yes	No	Yes	5.5	No	SR	No	No
8	Watching 619-3	S3	(RB)	Yes	No	Yes	6.0	No	SR	No	No
9	Machete Lake	S3	(RB)	Yes	No	Yes	9.0	No	NM	Yes	No
10	Watching 619-2	S3	(RB)	Yes	No	Yes	6.5	No	NM	Yes	No
11	Bonaparte	S3	RB	Yes	Yes	Yes	2.5	No	CR	No	No
12	Whitewood 74-9	S3	RB	Yes	Yes	Yes	2.5	No	CR	No	No
13	Haggard	S3	RB	Yes	Yes	Yes	3.0	No	CR	No	No
14	Lupin 870-4	S3	RB	Yes	Yes	Yes	2.7	No	NM	No	No
15	Saul Lake	S3	RB	Yes	Yes	Yes	0.5	Yes	CR	No	Yes
16	Paul Creek	S3	RB	Yes	NC	Yes	2.0	No	CR	Yes	No
17	Meadow Creek	S3	RB	Yes	Yes	Yes	1.3	No	SR /NM	No	No
18	Moore Creek	S3	RB	Yes	Yes	Yes	2.0	No	NM	No	No
19	Cannell	S3	UN	Yes	No	Yes	7.0	No	NM	No	No
20	Watching 619-4	S3	UN	Yes	No	Yes	12.0	No	NM	No	No
21	Watching 619-5	S3	UN	Yes	No	Yes	5.0	No	NM	No	No
22	Whitewood 88-7	S3	RB	Yes	Yes	Yes	2.0	No	SR /NM	No	No

Note: RB= rainbow trout present; (RB)= suspected rainbow trout presence; UN = rainbow trout presence unlikely, but not inventoried; NC= not critical; NR= Not Recorded; SS = stream simulation; NM= no material; SR= sparse material; CR= contiguous rockfill.

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[1] *Forest Practices Code Stream Crossing Guidebook; A Working Draft for 1997/1998* (Poulin and Argent, 1997).

[2] *Oregon Department of Forestry: Compliance with Fish Passage and Peak flow Requirements at Stream Crossings Pilot Study Results* (Dent and Allen, 2000)

Appendix 2a. Evaluation of the opportunity for juvenile fish passage through culverts in the Kamloops Forest District during the week of June 11 through 18, 2001.

	New Installation Structure Location	FPC Class	Fish Presence	Passage Inferred by FPC Class	Passage Required by EES	Passage Required by DFO	Culvert Gradient	SCG Objectives[1]	Simulated Stream bed[2]	Stream Channel Width	Likelihood of Juvenile Fish
1	Nomans Lake	S3	RB	Yes	Yes	Yes	4.0	No	SS	No	No
2	A541468-11	S3	RB	Yes	Yes	Yes	NR	No	SR	Yes	No
3	Lorenzo Lake	S3	RB	Yes	Yes	Yes	0.7	No	NM	No	No
4	Allan Lake #1	S4	(RB)	Yes	Yes	Yes	0.9	No	SS	Yes	No
5	Allan Lake #2	S4	RB	Yes	Yes	Yes	1.5	No	SR	Yes	No
6	Face Lake - M	S4	UN	Yes	No	Yes	8.5	No	NM	Yes	No
7	Face Lake - N	S4	UN	Yes	No	Yes	4.0	No	SR /NM	Yes	No
8	Face Lake - S	S4	UN	Yes	No	Yes	9.0	No	NM	Yes	No
9	North Paxton	S3	(RB)	Yes	No	Yes	6.0	No	NM	No	No

Note: RB= rainbow trout present; (RB)= suspected rainbow trout presence; UN = rainbow trout presence unlikely, but not inventoried; NR= Not Recorded; SS = stream simulation; NM= no material; SR= sparse material; CR= contiguous rockfill.

[1] *Forest Practices Code Stream Crossing Guidebook; A Working Draft for 1997/1998* (Poulin and Argent, 1997).

[2] *Oregon Department of Forestry: Compliance with Fish Passage and Peak flow Requirements at Stream Crossings Pilot Study Results* (Dent and Allen, 2000)

Appendix 2b. Achievement of the 1997 Stream Crossing Guidebook [1] culvert installation objectives (embedment and slope).

Structure Location		Structure Type		CMP Embedded 0.3 m or 20 % of CMP Diameter or Height*			SCG Recommended Slope for CMPs[3]			SCG Installation Objectives Achieved
Replacement Structures		Prev.	New	20%	Obj.	Obj. Met	CMP Gradient	Objective	Obj. Met	
1	Darlington	R	PA	0.22	0.3	Yes	0.5	< 5 %	Yes	Yes
2	Whitewood 77-7	R	PA	0.24	0.3	Yes	0.5	< 5 %	Yes	Yes
3	Taweel	LB	PA	0.28	0.3	No	2.5	< 5 %	Yes	No
4	Bogmar Lake	R	PA	0.22	0.3	No	0.9	< 5 %	Yes	No
5	Wyse Lake	R	R	0.15	0.3	No	1.5	< 3%	Yes	No
6	Akehurst Lake	?	PA	0.3	0.3	Yes	3.0	< 5 %	Yes	Yes
7	Caverhill A54114	R	PA	0.25	0.3	No	5.5	< 5 %	No	No
8	Watching 619-3	LB	R	0.32	0.32	No	6.0	< 3%	No	No
9	Machete Lake	LB	R	0.4	0.4	No	9.0	< 3%	No	No
10	Watching 619-2	LC	PA	0.33	0.33	No	6.5	< 5 %	No	No
11	Bonaparte	R	R	0.48	0.48	No	2.5	< 3%	Yes	No
12	Whitewood 74-9	LC	PA	0.46	0.46	No	2.5	< 5 %	Yes	No
13	Haggard	LB	R	0.64	0.64	No	3.0	< 3%	Yes	No
14	Lupin 870-4	R	PA	0.25	0.3	No	2.7	< 5 %	Yes	No
15	Saul Lake	R	PA	0.39	0.39	Yes	0.5	< 5 %	Yes	Yes
16	Paul Creek	LC	R	0.7	0.7	No	2.0	< 3%	Yes	No
17	Meadow Creek	R	R	0.72	0.72	No	1.3	< 3%	Yes	No
18	Moore Creek	R	PA	0.28	0.3	No	2.0	< 5 %	Yes	No
19	Cannell	LB	R	0.46	0.46	No	7.0	< 3%	No	No
20	Watching 619-4	LB	R	0.36	0.36	No	12.0	< 3%	No	No
21	Watching 619-5	LB	R	0.36	0.36	No	5.0	< 3%	No	No
22	Whitewood 88-7	R	R	0.36	0.36	No	2.0	< 3%	Yes	No

Note: SCG = Stream Crossing Guidebook; PA= Pipe Arch Corrugated Metal Pipe; R= Round Corrugated Metal Pipe; NA= Not Applicable; NR = Not Recorded

[1] *Forest Practices Code Stream Crossing Guidebook; A Working Draft for 1997/1998* (Poulin and Argent, 1997).

Appendix 2b. Achievement of the 1997 Stream Crossing Guidebook [1] culvert installation objectives (embedment and slope).

Structure Location		Structure Type		CMP Embedded 0.3 m or 20 % of CMP Diameter or Height*			SCG Recommended Slope for CMPs[3]			SCG Installation Objectives Achieved
New Installation Structures		Prev.	New	20%	Obj.	Obj. Met	CMP Gradient	Objective	Obj. Met	
1	Nomans Lake	NA	R	0.28	0.3	Yes	4.0	≤ 3%	No	No
2	A541468-11	NA	PA	0.28	0.3	No	NR	≤ 5 %	NA /NR	No
3	Lorenzo Lake	NA	PA	0.3	0.3	No	0.7	≤ 5 %	Yes	No
4	Allan Lake #1	NA	PA	0.28	0.3	No	0.9	≤ 5 %	Yes	No
5	Allan Lake #2	NA	PA	0.3	0.3	No	1.5	≤ 5 %	Yes	No
6	Face Lake-M	NA	R	0.24	0.3	No	8.5	≤ 3%	No	No
7	Face Lake-N	NA	R	0.28	0.3	No	4.0	≤ 3%	No	No
8	Face Lake-S	NA	PA	0.22	0.3	No	9.0	≤ 5 %	No	No
9	North Paxton	NA	R	0.3	0.3	No	6.0	≤ 3%	No	No

Note: SCG = Stream Crossing Guidebook; PA= Pipe Arch Corrugated Metal Pipe; R= Round Corrugated Metal Pipe; NA= Not Applicable; NR = Not Recorded

[1] *Forest Practices Code Stream Crossing Guidebook; A Working Draft for 1997/1998* (Poulin and Argent, 1997).

Appendix 2c. Comparison of the assessment techniques of the opportunity for juvenile rainbow trout passage through culverts.

Structure Location		FPC Classification	Fish Presence	Velocity	Access provided for 50mm RB based on velocity [1]	Access provided using physical parameters [2]
Replacement Structures						
1	Darlington	S3	RB	0.05	Yes	Yes
2	Whitewood 77-7	S3	RB	0.6	No	Yes
3	Taweel	S3	RB	0.47	No	No
4	Bogmar Lake	S3	RB	NR	No	No
5	Wyse Lake	S3	(RB)	0.61	No	No
6	Akehurst Lake	S3	RB	0.56	No	No
7	Caverhill A54114	S3	(RB)	NR	?	No
	Watching 619-3	S3	RB	1.17	No	No
9	Machete Lake	S3	(RB)	2.0	No	No
10	Watching 619-2	S3	RB	1.6	No	No
11	Bonaparte	S3	RB	1.2	No	No
12	Whitewood 74-9	S3	RB	0.74	No	No
13	Haggard	S3	RB	0.79	No	No
14	Lupin 870-4	S3	RB	1.63	No	No
15	Saul Lake	S3	RB	0.15	Yes	Yes
16	Paul Creek	S3	RB	1.19	No	No
17	Meadow Creek	S3	RB	1.17	No	No
18	Moore Creek	S3	RB	0.42	Yes	No
19	Cannell	S3	(RB)	1.7	No	No
20	Watching 619-4	S3	UN	NR	?	No
21	Watching 619-5	S3	UN	1.01	No	No
22	Whitewood 88-7	S3	RB	1.1	No	No
New Installs						
1	Nomans Lake	S3	RB	0.9	No	No
2	A541468-11	S3	RB	0.45	No	No
3	Lorenzo Lake	S3	RB	0.19	Yes	No
4	AllanLk #1	S4	(RB)	NR	NR	No
5	AllanLk #2	S4	RB	NR	NR	No
6	FaceLkM	S4	UN	1.32	No	No
7	FaceLkN	S4	(RB)	1.24	No	No
8	FaceLkS	S4	UN	0.67	No	No
9	North Paxton	S3	RB	0.54	No	No

RB= rainbow trout present; (RB)= suspected rainbow trout presence; UN = rainbow trout presence unlikely but not inventoried; NR = not recorded; ? = unknown.

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[1] *Analysis of fish swimming performance data* (Hunter and Mayer, 1986).

[2] *Oregon Department of Forestry: Compliance with Fish Passage and Peak flow Requirements at Stream Crossings Pilot Study Results* (Dent and Allen, 2000)

Appendix 3.

Data used to Evaluate the Habitat Loss Associated with Culvert Installation on Fish-Bearing Streams

Appendix 3a. Stream habitat loss and/or alteration associated with the installation of culverts in the Kamloops Forest District.

Replacement Structure Location		Determinants of Habitat & Alteration Loss				Instream Habitat Alteration or Disruption Associated with Culvert Installation		
		Structure Type	Bankfull Width (m)	CMP Diameter (m)	CMP Length (m)	Loss Due to Encroachment[1]	Benthic Loss (m^2)[2]	Totals (m^2)[3]
1	Darlington	PA	1.50	1.65	10.6	0	17.49	17.49
2	Whitewood 77-7	PA	2.30	1.85	13.0	5.85	24.05	29.9
3	Taweel	PA	2.00	2.10	14.0	0	29.4	29.4
4	Bogmar Lake	PA	1.60	1.60	10.6	0	16.96	16.96
5	Wyse Lake	R	2.40	1.00	10.7	14.98	10.7	25.68
6	Akehurst Lake	PA	2.30	1.90	15.0	6.0	28.5	34.5
7	Caverhill A54114	PA	1.90	1.85	13.2	0.66	24.42	25.08
8	Watching 619-3	R	1.80	1.60	16.0	3.2	25.6	28.8
9	Machete Lake	R	1.70	2.00	15.3	0	30.6	30.6
10	Watching 619-2	PA	2.20	2.20	14.0	0	30.8	30.8
11	Bonaparte	R	3.80	2.40	24.3	34.02	58.32	92.34
12	Whitewood 74-9	PA	4.00	3.60	11.2	4.48	50.18	54.66
13	Haggard	R	4.50	3.20	16.6	21.58	53.12	74.7
14	Lupin 870-4	PA	2.80	1.85	12.1	11.49	22.38	33.87
15	Saul Lake	PA	3.30	2.10	16.0	19.2	33.6	52.8
16	Paul Creek	R	3.30	3.50	20.0	0	70	70
17	Meadow Creek	R	4.40	3.60	16.6	13.28	59.76	73.04
18	Moore Creek	PA	3.30	2.15	14.0	16.1	30	46.1
19	Cannell	R	2.40	2.30	17.0	1.7	39.1	40.8
20	Watching 619-4	R	2.00	1.80	16.0	3.2	28.8	32.0
21	Watching 619-5	R	2.50	1.80	18.0	12.6	22.68	35.28
22	Whitewood 88-7	R	3.30	1.80	16.8	25.2	30.24	55.44
Totals						**193.5**	**736.7**	**930.2**

[1] Encroachment = (natural stream channel width – culvert diameter) * culvert length
[2] Benthic Loss = (culvert diameter * culvert length)
[3] Total Instream Habitat Alteration/Disruption Associated with Culvert Installation = (Encroachment + Benthic Loss)

Appendix 3a. Stream habitat loss and/or alteration associated with the installation of culverts in the Kamloops Forest District.

New Installation Structure Location		Determinants of Habitat & Alteration Loss				Instream Habitat Alteration or Disruption Associated with Culvert Installation		
		Structure Type	Bankfull Width (m)	CMP Diameter (m)	CMP Length (m)	Loss Due to Encroachment[1]	Benthic Loss (m^2)[2]	Totals (m^2)[3]
1	Nomans Lake	R	2.30	2.30	14.2	0	32.2	32.2
2	A541468-11	PA	2.30	2.13	13.3	2.26	28.3	30.56
3	Lorenzo Lake	PA	2.20	1.90	12.2	3.66	23.18	26.84
4	Allan Lake #1	PA	1.00	2.13	14.0	0	29.82	29.82
5	Allan Lake #2	PA	1.00	1.90	15.0	0	28.5	28.5
6	Face Lake-M	R	0.80	1.20	13.0	0	15.6	15.6
7	Face Lake-N	R	1.20	1.40	12.9	0	18.06	18.06
8	Face Lake-S	PA	1.00	1.70	13.0	0	22.1	22.1
9	North Paxton	R	2.00	1.50	12.0	6.0	18.0	24.0
Totals						**11.9**	**215.5**	**227.7**

PA = pipe arch corrugated metal pipe; R = round corrugated metal pipe

[1] Encroachment = (natural stream channel width - culvert diameter) * culvert length
[2] Benthic Loss = (culvert diameter * culvert length)
[3] Total Instream Habitat Alteration/Disruption Associated with Culvert Installation = (Encroachment + Benthic Loss)

Appendix 3b. Sedimentation

Structure Location		Limited Potential for Sediment Input Via:			
Replacement Structures		**Road Drainage**	**Lack of Re-Vegetation**	**Extensive Road ROW Width**	**Livestock Trampling**
1	Darlington	No	No	No	No
2	Whitewood 77-7	Yes	Yes	Yes	Yes
3	Taweel	No	Yes	No	No
4	Bogmar Lake	Yes	Yes	Yes	Yes
5	Wyse Lake	No	Yes	Yes	Yes
6	Akehurst Lake	Yes	Yes	Yes	Yes
7	Caverhill A54114	No	No	No	No
8	Watching 619-3	Yes	Yes	No	No
9	Machete Lake	Yes	No	No	No
10	Watching 619-2	No	Yes	Yes	No
11	Bonaparte	No	Yes	Yes	No
12	Whitewood 74-9	No	Yes	No	No
13	Haggard	No	Yes	Yes	No
14	Lupin 870-4	No	No	No	No
15	Saul Lake	Yes	Yes	Yes	Yes
16	Paul Creek	Yes	Yes	No	Yes
17	Meadow Creek	No	No	No	Yes
18	Moore Creek	No	No	No	Yes
19	Cannell	Yes	Yes	No	Yes
20	Watching 619-4	No	Yes	No	Yes
21	Watching 619-5	Yes	Yes	Yes	Yes
22	Whitewood 88-7	No	Yes	No	No
Totals		**13**	**6**	**13**	**11**
New Installations					
1	Nomans Lake	No	No	No	No
2	A541468-11	Yes	No	No	No
3	Lorenzo Lake	No	No	No	No
4	Allan Lake #1	No	No	No	No
5	Allan Lake #2	No	No	No	No
6	Face Lake-M	No	Yes	No	No
7	Face Lake-N	Yes	Yes	No	No
8	Face Lake-S	Yes	Yes	No	No
9	North Paxton	Yes	Yes	No	No
Totals		**5**	**5**	**9**	**0**

ROW = right-of-way